Section VII:
M&V for Water Projects

This section provides information on how to measure and verify on-site water and energy savings associated with water conservation measures (WCMs) installed at federal facilities. Chapter 26 of this section provides an introduction to M&V for water projects; Chapters 27 through 31 describe method-specific approaches. The content of these chapters is summarized in the following table.

Chapter	Method Description	Method Number
27	Stipulated flows and operating schedules for plumbing devices	WCM-A-01
28	Metered flows and stipulated or metered durations for plumbing devices	WCM-A-02
29	All water uses compatible with sub-metering or monitoring	WCM-B-01
30	All water uses compatible with whole-facility metering	WCM-C-01
31	Calibrated computer simulation analysis of water-consuming systems	WCM-D-01

26

Introduction to Water Conservation Measurement and Verification

26.1 Introduction

This chapter provides background information on water conservation opportunities, M&V issues relating to water conservation, and overviews of various M&V methods that follow the framework of Options A, B, C, and D. Some of the information and text in this section comes directly from the 1997 version of the International Performance Measurement and Verification Protocol (IPMVP). The IPMVP (see www.ipmvp.org) contains additional information and references that may be useful in developing water conservation projects and plans for measuring and verifying savings.

26.2 Water Conservation Measures

Water resource efficiency has become one of the most successful tools that water and sewer providers can use to limit and manage the increasing costs of providing water and treating wastewater. A partial list of water conservation measures that Federal agencies can consider includes the following:

- Replacing components of older plumbing systems with water-saving equipment such as ultra-low-flow toilets (ULFTs), high-efficiency shower heads, aerators, and self-closing valves.
- Eliminating continuously flowing urinals, lab drains, drinking fountains, and other similar devices.
- Replacing once-through cooling devices for space-cooling, icemaking, and other purposes with closed-loop or air-cooled systems.
- Improving technologies and management techniques for boilers, dishwashing, laundry, and other special purposes.
- Identifying and repairing all leaks promptly (an operations and maintenance measure.
- Maintaining proper pressure through the use of pressure regulating valves (PRVs).
- Decreasing the use of water for landscaping by implementing xeriscaping and more efficient irrigation systems and practices.

- Installing graywater, rainwater, and reclaimed water-recycling technology for flushing and/or irrigation
- Installing monitoring equipment and sub-meters as needed so that increases in consumption over time can be quickly rectified

On-site savings, or savings that accrue directly to the facility, can result from reduced water supply charges, sewer charges, and/or energy costs.The greatest savings are often the result of lowered energy costs, for example, reduced water heating, pumping, and treatment needs. Energy savings often occur at facilities that use pumps to boost water pressure or to irrigate with groundwater, or at facilities with their own water-treatment systems.

In some warm, humid climates, hot water is also used to temper cold water in toilet and urinal cisterns in order to prevent condensation problems. In some very cold climates, hot water is bled into cisterns and cold water pipes to prevent freezing problems. Although fixture retrofits may greatly reduce hot water needs for these purposes, it is generally preferable not only to retrofit the fixtures, but also to reduce or eliminate the need for hot water by using strategies such as insulating cisterns and pipes, using passive solar techniques to heat cold water pipes (which can also reduce cooling loads), and other techniques.

Unfortunately, certain water measures may actually increase on-site energy use. For example, switching from a once-through cooling system to a closed-loop or air-cooled system can greatly reduce water usage, but it requires fans or pumps and can lower cooling efficiency, depending on the temperature of the incoming water. Agencies should take such increases in energy demand into account when determining overall savings accruing to a specific site.

On-site water conservation can also result in off-site energy savings. Though federal performance contracts will not include payments for these savings, there may be value in considering them for utility incentive programs.

26.3 Information on Federal Water Conservation Programs

The Energy Policy Act of 1992 (EPAct) and Executive Order 13123 call for the implementation of water conservation projects and provide the authority to use performance contracting to finance these projects. Subtitle F, Section 152, of EPAct amends Section #541 of the National Energy Conservation Policy Act (42 USC 8252) to explicitly include water with the requirement related to energy use. The same section also directs federal agencies to install in the facilities they own, to the maximum extent practicable, all energy and water conservation measures with a payback period of 10 years or less. Subtitle F, Section 152, of EPAct amends 42 USC 8287 to authorize the use of energy-saving performance contracting, and Section 152 authorizes and encourages agencies to participate in incentive programs offered by gas, water, or electric utilities to finance the installation of energy and water efficiency measures required by EPAct.

Executive Order 13123, "Energy and Water Efficiency in Federal Facilities," Section 303, further directs agencies to identify conservation opportunities and install cost-effective conservation measures. Finally, Section 401 directs agencies to use innovative financing and contractual mechanisms including, but not limited to, utility demand-side management programs and energy-savings performance contracts to meet the water and energy goals and requirements.

DOE's Federal Energy Management Program (FEMP) is working with federal agencies to help achieve these goals. FEMP provides technical support to federal facility managers to help identify opportunities for successful water conservation projects. FEMP's technical assistance program offers a range of services, including project and financing assistance, software tools, and training.

Federal Water Working Groups

The Federal Water Working Group, established by the Interagency Energy Management Task Force and facilitated by the FEMP Water Conservation Program, focuses on water management awareness, technical assistance, training, water conservation plan development, and partnerships with industry and professional associations. The Federal Utility Partnership Working Group consists of representatives from water, wastewater, electric and gas utilities, and federal agencies. The group explores ways that federal agencies and utilities can work together to create efficiency projects and programs that benefit all parties.

Project Assistance

For site-specific projects, FEMP can help plan and develop projects, leverage resources, and provide information on water-efficiency technologies. As part of the project-screening process, FEMP has developed WATERGY, a spreadsheet model that uses water/energy relationship assumptions to estimate potential water and associated energy savings at a facility or building.

Project Financing Assistance

The FEMP Water Conservation Program also supports federal agency use of alternative financing mechanisms. These include ESPC and utility contracts for water conservation projects.

Training and Workshops

FEMP offers a Water Resource Management training course and, for a fee, can design and implement agency-specific water conservation workshops. Training information and WATERGY software, copies of water conservation case studies, and other information resources can be obtained from the FEMP Help Desk.

26.4 M&V Options for Water Conservation Measures

This part provides a brief overview of methods for determining water savings. The methods follow the framework of the IPMVP's Options A, B, C, and D. An overview of the M&V options is presented in Chapter 2.

The four M&V options for WCMs are as follows:

- **Option A:** Focuses on physical assessment of equipment and system changes to ensure that installation is to specification. Key performance factors (e.g., gallons per flush) are determined with spot measurements or manufacturer's data, and operational factors (flushes per hour) are stipulated based on an analysis of historical data and/or one-time, spot, or short-term measurements.
- **Option B:** Savings are determined after project completion by using short-term or continuous measurements taken throughout the term of the contract at the device or system level. Both performance and operational factors are monitored.
- **Option C:** Savings are determined after project completion at the whole-building or facility level using current-year and historical utility meter or sub-meter data.
- **Option D:** Savings are determined through simulation of facility components and/or the whole facility. The simulation is calibrated with end-use or whole-facility metering data. Simulations can include anything from spreadsheets using fixture unit data to sophisticated programs using psychometric calculations.

M&V methods defined for these options are summarized in part 26.7.

26.5 Water Conservation M&V Issues

26.5.1 M&V Cost Consideration

The value of a WCM should be considered when deciding how much effort to put into M&V activities. The value of the M&V information should not exceed the cost of obtaining the information. Thus, when examining water efficiency opportunities with small amounts of water savings, ESCOs and federal agencies may need to apply simplified versions of the M&V techniques used for energy efficiency. Exceptions to this approach exist when the water-efficiency projects lead to significant direct or indirect energy savings.

26.5.2 Water Rates

Water and sewer rates vary tremendously throughout the country. Many locations do not charge on the basis of consumption and/or do not meter the service. Other jurisdictions charge only for water consumption and issue a flat bill for sewer services. Most areas, however, bill for water and sewer service from meter readings, and a large percentage of charges are consumption based. These are areas where performance contracting can be most successful for all parties involved.

As with energy-efficiency projects, the goal of a performance contract is to reduce facility operating costs. The M&V approach selected should be designed to provide water and energy savings information in such a way that cost savings can be estimated. Therefore, the M&V plan should ensure that:

- Appropriate energy, water, and sewer rate schedules are used to calculate cost savings.
- Agreements are made between the federal agency and the ESCO on how changes in rates (e.g., $/1000 cubic feet) and changes in how the charges are calculated (flat rate changed to volumetric rate) will affect any savings guarantees or shared savings arrangements.
- The water (and energy) savings data and calculations can be used to determine cost savings—i.e., all the data used to calculate a water, sewer, and energy bill are available and documented.

26.5.3 Meter Accuracy and Metering

The quality and accuracy of water meters varies significantly according to the type, initial quality, age, calibration efforts, and maintenance of individual meters. A historical consumption level could be substantially lower than actual flow. The encoded register meters used by most water utilities tend to register anywhere from zero to 25% low (IPMVP, Section 4.5.1) and thus may not precisely represent consumption after long periods of service. Therefore, using historical water meter data may not provide an accurate baseline for purposes of a performance contract and can adversely affect savings projections.

Recommendations for metering include the following:

- All meters installed to verify savings should comply with appropriate American Water Works Association (AWWA) accuracy standards. Regular calibration should be part of any M&V plan that relies on the use of either whole-facility or sub-meters for the calculation of savings.
- Sub-meter quality must be addressed if these meters are used to measure quantities involved in determining savings. Degradation of low-quality meters can result in artificially low flow readings.
- If existing water meters are used in the M&V effort, project partners should consider either testing the accuracy of the meters or installing meters independent of the utility meters. For example, adjusting three years of istorical water-use data, based only on recent calibration may not account properly for meter inaccuracies that varied throughout the last three years.

Flow measurements can be made either with flow meters or by volumetric means. Suitable flow meters are selected for appropriate accuracy and have flow ratings that conform to field conditions. Flow rates can also be determined by measuring how much water (i.e., its volume) is used or discharged during a measured time interval. For example, water discharged from a faucet is collected for a timed period of 2 minutes, and is found to be exactly 5 gallons when measured; the flow rate is 5 gallons divided by 2 minutes, or 2.5 gpm (gallons per minute). Volumetric measurements are usually used to determine how much water is discharged during a set cycle, such as one flush of a water closet. Dishwashers and clothes washers also have set cycles, although care must be taken to recognize possible variations such as water-saver cycles or extra rinse cycles.

Spot measurements are useful not only to quantify water consumption but also to make sure specific devices are assigned to appropriate groups (when sampling is used to characterize the entire population of devices) and to verify that all devices assigned to the sampling group have similar performance characteristics.

Flow measurements should be made with integrating flow meters, either by direct reading or perhaps through an energy management system (EMS), and with or without automatic recording. Suitable flow meters will be selected for appropriate accuracy and have flow ratings that conform to field conditions. The readout from integrating flow meters will be in volumetric units, typically gallons or cubic feet, often with a multiplier. Knowledge of the correct multiplier is critical. Readings must be taken and recorded regularly, either monthly or at a more frequent interval.

Fixtures of a similar type that have the same flow characteristics can be grouped together. Units of measure should be consistent with the fixture type, but all should be expressed with a common volumetric measure (usually gallons) so those totals can be aggregated easily. For example, water consumption for water closets might be expressed in gallons per flush, while shower consumption is expressed in gallons per minute. Water consumption per unit of measure must then be quantified in the same units, and periods of service must be expressed in consistent terms (such as flushes per day, or minutes per shower and showers per day). In some facilities the utilization factor may change seasonally (e.g., a school summer vacation period); separate data will be needed for each season.

26.5.4 Nameplate Data

ESCOs and agencies should use great caution if they rely on nameplate data for M&V calculations of baseline water-use or savings. The water consumed by most water fixtures can be easily adjusted to go well above or below nameplate specification. Actual use for existing fixtures can be determined by short-term metering or other techniques. All newly installed equipment should be tested and adjusted as needed.

The following are two examples (excerpted from the 1997 IPMVP, Section 4.5.1):

Toilets

Existing toilets that are nominal five-gallon-per-flush (GPF) models (pre-1980) are often assumed to consume 4.5–5.0 GPF. “Low-flush” toilets from the 1980s are generally said to have a nominal flush volume of 3.5 gallons. These assumptions are not always valid, because significant variations are possible due to internal refill settings and different flush mechanisms. The flush volume of “flushometer” valve toilets may vary by as much as several gallons depending on water pressure, valve condition, and, in the case of piston-type flush valves, the position of the adjustment screw. Even gravity tank toilet flush volumes may vary somewhat with water temperature and pressure, although these variations may be relatively minor.

An assumption must also be made for the number of flushes per day. This is particularly difficult since it requires an understanding of how building occupants live and work and how often they "double-flush" the toilet. Although there has been much discussion of the need to double-flush low-consumption toilets, some information indicates that higher-consumption toilets are being double-flushed as well.

The actual measured consumption of "water-wasting" toilets varies from 3.5–7 GPF. A stipulation of unit flush volumes for existing toilets ignores the fact that a part of the baseline consumption and later water savings resulting from toilet replacement (or repair/retrofit of existing toilets) comes from ending internal leaks in the old toilets. These leaks can originate with seeping/leaking flappers, ball cocks out of adjustment, leaking supply lines, etc. Leaks can be identified by using techniques such as dye tablets in toilets or looking for variances from normal consumption rates. Quantifying baseline losses due to leaks is difficult, however, and simple stipulations should be used with caution.

Shower Heads

Existing pre-1990 shower heads are often assumed to flow at 5 gallons per minute (GPM). However, field studies suggest that actual flow rates are closer to 4 GPM, and sometimes even lower. Flow rates may vary, depending on the specific shower head model, water pressure, and condition of the fitting, from well over 5 GPM to less than 1 GPM. The flow rates of most older shower heads vary significantly with water pressure and long-term deposition. Of course, an assumption must be made about the number and duration of showers per day.

Taking Spot Flow Measurements of Shower Heads and Toilets

Taking spot flow measurements of shower heads and toilets can be done by using small flow meters or by timing the filling of a container of known volume. Unlike toilets, for which measuring unit flush volumes involves the often difficult installation of inline flow meters on water lines, approximating showered flow rates can be accomplished by using a graduated container or calibrated measuring device (e.g., the Water Weir), which does not require a timer. After determining flow rates and flush volumes, an assumption must still be formulated concerning usage rates (number of flushes per day, number and duration of showers per day).

26.5.5 Baseline Adjustments

Baseline adjustments, which may be required during the service phase of an ESPC, are a common area of contention in performance contracts. In general, one might expect baseline adjustment changes to fall into one or more of the following three categories:

1. Clearly expected and predictable annual variations. For example, changes in rainfall that affect irrigation requirements or changes in a building's occupancy that affects water closet use. These are usually dealt with through defined procedures for each identified factor in the savings formulas. Such procedures might include the use of regression analyses to calculate savings using current-year weather or occupancy data (Options B and C), stipulating the use of typical weather or occupancy data (all options), or agreements to modify baseline calculations by using current-year weather or occupancy data (Options A and D).

2. Potential changes that are predictable, although describing a detailed calculation method for them is not reasonable given the unknowns about each situation or the cost of developing numerous "what-if" scenarios. For example, adding more occupancy hours to a library, closure of a facility, adding new wings on a hospital, or acquiring more landscape irrigation acreage. These changes require a conceptual approach defined in the agreement between the ESCO and the agency, rather than a method to cover each eventuality. Examples of such conceptual approaches are (a) defining which party is responsible for decreases in energy-savings associated with different categories of changes, (b) defining whether an ESCO is able to claim credit for additional savings associated with different categories of changes, (c) defining the categories of changes eligible for baseline adjustments, (d) defining which party can request a baseline adjustment, and (e) when this can be done, what time period of the service phase the adjustment will cover, and what approval process is required.
3. Potential changes that are not obviously predictable. For example, changing the use of a facility from warehouse to office space. These potential changes require either (a) agreement clauses that allow for adjustments for unexpected changes and/or (b) the use of a "re-open" clause that allows either party to renegotiate the baseline "model." These clauses would be part of or consistent with termination, default, and arbitration clauses contained in the agreement between the agency and the ESCO. Determining which of the these three categories each potential change fits into can be done by preparing a list of potential changes associated with each water conservation measure or by defining which baseline factors are constant or are assumed to be constant, and which can vary.

The following are some notes on baseline adjustments:

- Even if utility meter analysis is used to determine savings, a complete and detailed audit (e.g., investment-grade audit) is required. If the baseline conditions are not well documented, it becomes difficult, if not impossible, to properly adjust them when they change and adjustments to payment calculations are required. For example, if a toilet valve retrofit takes place in a building with 100 toilets, and later (during the service phase) the number of toilets is increased to 125, post-installation water-use may be more and calculated savings may be less. If there were no records of how many toilets were originally in place, however, the baseline could not be adjusted to properly reflect the amount of "true" savings and how much the ESCO should be paid.
- With Option A, baseline adjustments are less likely to be required because many of the factors are stipulated, such as occupancy. This is one reason why Option A can be less accurate but easier and less expensive to implement.
- Option B involves metering techniques. Baseline capacity values are assumed to be constant (e.g., baseline sprinkler head flow rates or water closet gallons per flush), but baseline "operating values" can be changed by using post-installation monitoring data (e.g., hours per year of irrigation and flushes per day).

- For Option C, billing analysis, either typical values or post-installation values are defined for baseline and post-installation independent variables that influence water-use (e.g., weather and occupancy). It is important to agree in advance on the variables that will be used.
- For Option D, calibrated simulation, it is important to agree in advance on the model to be calibrated and what changes will require a new simulation run. For most retrofit and new construction projects, baseline and post-installation models are calibrated and then run with typical input data (e.g., weather data). Thereafter, they are typically not modified unless major changes occur at the site. Annual verifications are expected, but normally the models do not need to be run again unless changes occur to the installed WCMs.

26.5.6 Notes on Outdoor Water Use

Establishing Baseline Water Consumption

Unless there is a separate meter of outdoor water use, the usual first step is to evaluate the entire facility's water consumption by using several years of data to compare seasonal irrigation use with non-seasonal irrigation use. The difference can be used for a baseline but should be adjusted for changes in temperature, rainfall, evapotranspiration, and/or other relevant factors, if possible. If the water utility separately meters outdoor water use, then establishing baseline use is relatively simple, except for concerns regarding the accuracy of older utility meters. The difficulty with monitoring whole-building consumption is that outdoor water use can be so variable that desegregating that end-use from a facility's water load, which is itself variable in use, can be problematic.

If outdoor end uses are not separately metered by the water utility, strong consideration should be given to installing new meters to track outdoor end uses.

An alternative to establishing baseline outdoor use, without new or existing metering, depends on the system having a relatively constant flow rate and being operated on a relatively regular schedule. For example, the consumption of a sprinkler system that flows constantly at “X” cubic feet per minute (CFM) for “Y” hours per day can be reasonably estimated. It is common, however, for operators to vary the operation of outdoor systems, depending on perceptions of need. Detailed information about how the system is operated is necessary to place a high degree of confidence in calculated estimates of use, unless the investment in the project is small enough to tolerate a relatively low degree of confidence in the estimate of baseline use.

Methods of Monitoring Savings

In comparison to metered observations, estimating savings from outdoor water-use projects by stipulating or assuming changes in the system's operation is particularly difficult. Efficiency improvements to outdoor water end-uses generally are focused on either modifying the schedule of irrigation or improving the efficiency of water delivery to the lawn or crops.

Modifying the schedule of irrigation is based on varying irrigation times with weather and the evapotranspiration rate. These savings may be specific to the plant species involved and certainly vary according to the region and even the microclimate. Increasing the delivery efficiency of water involves the use of irrigation technologies (e.g., "drip irrigation" or more efficient sprinkler technologies) or other changes that result in lower evaporative losses. These savings also depend on local climate and evapotranspiration rate as well as plant species. Even metered baseline and post-retrofit data may need to be "normalized" with changing weather.

26.5.7 Notes on Graywater Use

Establishing Baseline Consumption
Establishing baseline consumption depends on which end use(s) the graywater is displacing. The two most common end uses are irrigation and toilet/urinal flushing. In each case, the whole-facility meter, end-use metering, or stipulation approaches for assessing baseline consumption can apply.

Methods of Monitoring Savings
If graywater is completely displacing potable water for a specific end use, and the graywater consumption level can be shown to represent a one-to-one correlation to that of the displaced potable water, then the complications of determining a baseline are not an issue. For post-installation graywater measurements, it may be easier to meter the flow of graywater into a system. If the graywater originates from multiple sources, then it would be easier to monitor the use of graywater at the end use.

26.5.8 Demand Savings

Some water utilities have demand charges that are linked to water meter size. Water conservation projects therefore may not realize any demand savings unless the water meter is replaced with a smaller one, or if it can be shown that a larger meter would have been required in the absence of the WCMs. In these situations, any demand savings will depend on the change in meter size and the serving utility's schedule of charges.

Changes in water supply demand may also affect sewer charges. Sewer charges are sometimes based on how much water is delivered to the utility's supply meter during a specified period, such as one winter month. Demand savings from reduced sewer charges resulting from water conservation measures can be calculated from the sewer charge before and after the improvements are made.

26.5.9 Sanitary Considerations

Most domestic water use is for cleaning and transporting waste. These are sanitary functions that use equipment and systems designed to comply with carefully crafted sanitary codes and standards. Saving water by using methods that compromise system performance is unacceptable. For example, when graywater systems are installed, special attention should be taken to prevent cross connections and prolonged retention periods.

26.6 General Considerations for Selecting an Appropriate M&V Option and Method

26.6.1 Whole-Building Analysis—Option C

The most common approach to M&V for water is the "whole-building" or main-meter approach, in which all aspects of water usage are combined into a single M&V analysis strategy.

To establish a baseline figure on which all savings calculations are based, a typical method is to average the previous 2 to 3 years of consumption data (e.g., directly from past water/sewer bills) and convert this number into daily usage. This calculation will typically be in gallons, but it can also be in cubic feet or cubic meters. The baseline figure will be in units of water/sewer use (e.g., average daily consumption), which is not a monetary amount. During the term of the performance contract, this baseline figure can be converted into a monetary amount using the current water/sewer rate in that community.

Understanding and tracking key parameters at the facility (e.g., population changes) are important in accurately defining a baseline and estimating building-wide water savings estimates. These parameters are used in adjusting the baseline as the parameters change over time.

As an added benefit, detailed and frequent (even continuous) building-wide water consumption metering data may also provide important information for assessing equipment performance.

26.6.2 Sub-meters and Data Loggers—Option B

Water sub-metering should be considered for the following:

- Facilities with significant single process use or outdoor water use.
- Large facilities with distinct water-use areas that can be accurately metered and monitored; examples include individual buildings on military bases, cooling towers, laundry facilities, or graywater systems.
- Facilities for which the agency wants to achieve or verify savings for a discrete portion.

One benefit of sub-metering is that it provides ongoing information on the performance of individual systems. This can provide the federal agency and ESCO with early warnings of system problems, and it may prove helpful if troubleshooting is required. For example, a leak that could easily nullify all water savings resulting from a water measure can be more easily identified and repaired by regular reading of submeters.

Water sub-metering should be considered in order to make the user (e.g., individual departments) accountable for his or her water use. For example, reductions in water consumption are being experienced in multifamily properties that use sub-metering as a conservation strategy. Thus, water sub-metering can both promote savings and act as a means of detailed verification.

Sophisticated water meter data loggers have been developed that can greatly assist in the M&V of water measures. The use of data loggers can often help identify actual savings when a facility faces considerable and/or uncontrollable changes in factors that affect water use (e.g., occupancy, weather). Changing factors can often be too expensive and nearly impossible to measure. With data loggers, water savings per fixture use can be measured rather than relying on the measurement of overall reductions in water use.

26.6.3 Use of Stipulations—Option A

As discussed in part 26.5.4 using nameplate data for water-consuming devices can introduce significant uncertainty into savings calculations. Thus, this approach should be used with caution and only for projects in which the economic value is low, where there is little risk of not obtaining the project, and/or for which assumptions can be tested or confirmed with current or historical data.

While a stipulation may be the least expensive method of determining post-installation unit consumption rates, water savings calculations still have a significant variable—the number of uses (e.g., flushes, showers, irrigation schedule, and their duration).

26.6.4 Use of Simulation Tools—Option D

This M&V approach can be considered a combination of Options A and B or A and C, in which meter data are combined with calculations using analysis tools such as spreadsheets, vendor computer programs, or sophisticated simulation programs that estimate water use in evaporative cooling systems, for example. Caution should be used when working with any simulation tool to ensure that the results are reasonable and documented. See Chapter 24 for general information on calibrated simulation for energy efficiency projects.

26.6.5 Using Multiple M&V Options at a Single Facility

When a variety of measures are installed at a single facility, it is not recommended that different M&V options be used to calculate savings. For example, Option B should not be used to calculate savings from an irrigation retrofit when Option C is then used to calculate the remaining savings at a facility, through a billing meter analysis and the subtraction of the irrigation system savings. This can lead to inaccuracies in savings estimates.

26.7 Summary of M&V for Water Conservation Measures

The following paragraphs and tables summarize the five M&V methods described in this document as they apply to WCMs. Each method is appropriate for different measure types and risk profiles. The descriptions in this document assist federal procurement and project managers as well as ESCOs in the selection of the most appropriate method. See part 26.6 for a discussion on selecting appropriate M&V methods.

26.7.1 Method WCM-A-01—Stipulation of Key Variables, No Metering

This method assumes that the federal agency and the ESCO are confident that unit water consumption can be defined and stipulated for each fixture type and that device usage schedules (flushes per month, hours of use, water schedule, or another parameter) can be quantified and stipulated based on the manufacturer's data and other available data. This M&V method is appropriate for projects in which water is conserved in either or both of these ways:

- Replacing existing plumbing fixtures (the baseline) with new fixtures designed to deliver water at low flow rates
- Delivering water during fewer and/or shorter intervals.

Example WCMs include new toilets, urinals, shower heads, and/or irrigation head retrofits; defined-cycle laundry and dishwashing retrofits; and irrigation and once-through pumping control conversions.

In this approach, as with all M&V methods, surveys are required to document existing (baseline) and new (post-installation) devices and their characteristics.

All values, however determined, are stipulated for the term of the agreement, subject to changes in the facility or its operation. The source(s) of stipulations may vary and can include manufacturers' ratings, published values for a range of flows typically associated with a given generic type of plumbing fixtures, and results from prior projects.

Water consumption savings are based on the following:

- Stipulated baseline consumption for each type of device
- Stipulated post-installation consumption for each type of device
- Number of devices, both baseline and post-installation, of each type
- Stipulated cycles or hours per year for each operating scenario, both baseline and post-installation.

26.7.2 Method WCM-A-02—Stipulation of Key Variables Using Spot or Short-Term Metering

This method is the same as method WCM-A-01 except that one-time, spot, or short-term metering is used to quantify key parameters. This method is used if the federal agency and ESCO want to verify savings with the simplicity associated with Option A, but also want to base stipulations on metering data. Thus, either or both of these can be done:

- Values for baseline and post-installation flow rate are determined one time with either spot measurements (e.g., averaging four measurements of representative toilets' water flow per flush) or short-term measurements (e.g., the average of two weeks of values to determine average daily flow rate for a sprinkler system).
- Operating hours or cycles per time period are determined with short-term metering.

Water consumption savings are based on the following:

- Baseline consumption for each type of device, based on metering data or other sources
- Post-installation consumption for each type of device, based on metering data or other sources
- Number of devices, both baseline and post-installation, of each type
- Stipulated cycles or hours per year for each operating scenario, both baseline-based and post-installation-based, using short-term metering or historical data.

26.7.3 Method WCM-B-01—Determining Savings from Plumbing Fixture and Other Water-Consuming-System Retrofits with the Use of Sub-Metering

This method is applicable to retrofits in which all or a sample of affected devices' (or systems') water consumption can be sub-metered and/or monitored. Because of the costs of this method, it is recommended for retrofits associated with the following: (a) water closets, urinals, irrigation, etc., with electronic controls that can be used to record operating patterns, or (b) systems that are already, or can easily be, sub-metered.

Examples of these measures are irrigation system retrofits and large-scale shower head retrofits in a locker room setting.

In this approach, as with all M&V methods, surveys are required to document existing (baseline) and new (post-installation) devices and their characteristics.

Water consumption savings are based on the following:

- Number of devices, both baseline and post-installation, of each type
- Measured baseline consumption, extrapolated to annual values, for each device or device category
- Measured (either continuously or during representative time periods and then extrapolated to annual values) consumption for each device or device category
- Baseline device counts, cycles, or hours of use are updated, as needed, using regressions/correlations with independent variables (e.g., occupancy and weather).

26.7.4 Method WCM-C-01—Determining Savings from Plumbing Fixture and Other Water-Consuming-System Retrofits with the Use of Whole-Facility Metering

This method is applicable to all water system retrofits when project consumption and/or water savings are large in comparison to the total consumption recorded on whole-facility meter(s). Because of this limitation, this method is recommended for water system retrofits that are large and comprehensive.

Examples of measures are graywater applications and large-scale plumbing fixture retrofits.

In this approach, as with all M&V methods, surveys are required to document existing (baseline) and new (post-installation) devices and their characteristics.

Water consumption savings are based on the following:

- Historical whole-facility water meter and independent variable (e.g., weather or occupancy) data
- Recorded whole-facility, post-installation consumption, and independent variable data
- Regression analysis to isolate the effects of the WCM from the other variables.

26.7.5 Method WCM-D-01—Determining Savings From Plumbing Fixture and Other Water-Consuming-System Retrofits with the Use of Calibrated Simulation Analysis

This method is applicable to retrofits in which baseline and post-installation water-use can be simulated and the simulation can be calibrated using whole-facility and/or end-use metering data. Because of the possible complexity and costs associated with this method, it is recommended for comprehensive retrofits for which Options B or C cannot be applied because of complex interactions and/or the effects of independent variables.

Examples of these measures are cooling tower retrofits and other HVAC types of projects.

In this approach, as with all M&V methods, surveys are required to document existing (baseline) and new (post-installation) devices and their characteristics.

There are several approaches for determining savings using simulation models. One approach involves the following:

- Simulation of the baseline system and then calibration of this simulation with end-use or whole-facility meter data
- Simulation of the post-installation system and then calibration of this simulation with end-use or whole-facility meter data
- Comparison of the baseline and post-installation models using actual or typical independent variables (e.g., occupancy and weather).

26.8 Pre- and Post-Installation Submittals

For each site, the ESCO submits a project pre-installation report that includes the following:

- A project description and schedule
- A pre-installation equipment survey
- Estimates of water savings
- Documentation of historical water utility billing data
- Site-specific M&V plan
- Schedule of project and M&V activities.

If the federal agency defines the baseline condition, the ESCO must verify an agreed-to pre-installation equipment survey.

The ESCO submits a project post-installation report following project completion and in that document defines projected savings for the first year. In addition, the report includes many of the components as in the project pre-installation report, adding information on actual rather than expected WCM installations.

The site-specific M&V approach may be prespecified in the ESPC between the federal agency and the ESCO and/or agreed to after the award of the project. In either case, before the federal agency approves the project construction, the ESCO must submit a final M&V plan that addresses the following:

- Overview of approach
- Specification of savings calculations, including units of measure

- Specification of data collection methods, schedules, equipment, and reporting format
- Identification and resolution of any other M&V issues.

26.9 Site-Specific M&V Plan

Every project or, as appropriate, group of similar projects must have an approved site-specific M&V plan before the installation of any WCMs. The minimum requirements for preparing a site-specific M&V plan, using a method described in these Guidelines, are as follows:

1. State which M&V method (chapter) of the M&V Guidelines will be used.
2. Describe the facility and the project and include information on how the project saves water (and energy) and what key variables affect the realization of savings.
3. Indicate who will conduct the M&V activities and prepare the M&V analyses and documentation.
4. Define the details of how calculations will be made. For instance, "List analysis tools and/or show the equations to be used."
5. Specify what metering equipment will be used, who will provide the equipment, its accuracy and calibration procedures, and how data from the metering will be validated and reported, including formats; electronic format data directly from a meter or data logger is required for any short- or long-term metering.
6. Define what key assumptions will be made about significant variables or unknowns. For instance, "actual weather data will be used, rather than typical-year data," or "water consumption will be metered for one full year for two of the six restrooms." Describe any stipulations that will be made and the source of data for the stipulations.
7. Describe any sampling that will be used, why it is required, sample sizes, documentation on how sample sizes were selected, and information on how random sample points will be selected.
8. Define the level of accuracy which should be achieved if not for the entire analysis, at least for key components. For instance, "Irrigation water flows will be measured at a sample of locations sufficient to provide a 90% confidence level and 10% precision."
9. Indicate how quality assurance will be maintained and repeatability confirmed. For instance, "The data being collected will be checked every month," or "To ensure accuracy, results will be subjected to third-party review by the XYZ Company."
10. Indicate which reports will be prepared, what they will contain, and when they will be provided.

If the site-specific M&V plan is to be developed independent of a method described in the M&V Guidelines, then the following information is required in place of item 1 above:

- Explain why none of the M&V methods in the Guidelines is applicable.
- Provide an overview of the method.
- Describe how baseline and post-installation inventories and equipment/system descriptions will be documented.
- Describe any spot, short-term, or long-term metering that will be conducted.
- Specify the analysis method for calculating savings.

	M&V Method and Option				
	WCM-A-01: No Metering (Option A)	**WCM-A-02: Spot or short-term metering of device water consumption and/or operating schedules (Option A)**	**WCM-B-01: Long-term end-use metering (Option B)**	**WCM-C-01: Whole-facility meter analysis (Option C)**	**WCM-D-01: Calibrated simulation (Option D)**
Device counts	Conduct survey and check to define level of accuracy	Same as WCM-A-01	Same as WCM-A-01	Same as WCM-A-01	Same as WCM-A-01
Device water consumption rates	Stipulate rates based on manufacturer or historical data	(a) Stipulated, based on manufacturer or historical data or (b) Spot or short-term, one-time (before and after) measurements of representative device water-consumption rates	Baseline based on metering during representative period before WCM installation. Post-installation, if required, metered during representative period each contract year or continuously	Not required	Required for calibration check, or possibly for future baseline modifications
Baseline operating schedule	Stipulated, based on historical data or other non-metering-based documentation	(a) Stipulated, based on historical data or other non-metering-based documentation or (b) Stipulated, based on some short-term baseline monitoring	If required, based on metering during representative period before ECM installation	Baseline water-use calculated using historical meter data	Possibly required as a calibration check or for future baseline modifications
Post-installation operating schedule	Stipulated, based on historical data or other non-metering-based documentation	(a) Stipulated, based on historical data or other non-metering-based documentation or (b) Stipulated, based on some short-term post-installation monitoring	If required, metered during representative period each contract year or continuous monitoring	Post-installation water use calcualted using historical meter data	Not required, unless as a check
Independent variables (e.g., weather and occupancy)	Not required	Not required	Monitored as required for baseline and post-installation water-use calculations	Monitored for use in regression analysis	Monitored for use in calibrating models and for "running" models

27

Stipulated Flows and Operating Schedules for Plumbing Devices

27.1 WCM Definition

Many water conservation projects focus simply on replacing existing plumbing devices (the baseline) with new devices. The new devices are designed to deliver water at low flow rates or low consumption per cycle during consistent operating schedules. Designs limit the flow and/or cycle consumption to fixed maximum values, usually stated in the product specifications. Other projects simply involve changing water consumption schedules.

For these projects, the operating schedules are known and consistent. Typical applications include water closet, urinal, irrigation sprinkler head and shower head conversions, and irrigation schedule changes.

This M&V method is appropriate only for water conservation projects in which, for the baseline and post-installation conditions, the following apply:

- Device flow rates and/or water consumption per cycle can be stipulated because the values are known or can be estimated with reasonable accuracy.
- Baseline and post-installation scheduled use of the water-consuming devices can be stipulated because usage patterns are known or can be estimated with reasonable accuracy, and operating schedules are consistent from one time period to the next.

27.2 Overview of Verification Method

Method WCM-A-01 assumes that the federal agency and the ESCO are confident that unit water consumption can be defined and stipulated for each device type and that operating cycles (flushes, hours of use, or other parameter) can be quantified and stipulated.

Surveys are required to document existing (baseline) and new (post-installation) devices (sprinkler heads, toilets, etc.) and characteristics. The surveys should include the following information in a set format, preferably in a matrix that allows each device type to be listed by location:

- Generic type of device
- Location
- Number of devices (of the same type and flow) counted in each location
- Unit of measure for each device group (gpm flow, gallons per flush, etc.)
- Period of service in consistent units (hours per day, flushes per day, etc.)
- Water consumption per unit of measure, existing devices (base case)
- Water consumption per unit of measure, new devices.

This method, unlike methods WCM-A-02 and WCM-B-01, does not require measurements or metering of water flow from individual devices or other water delivery devices. Therefore, it is a good idea to conduct a "reality check" of the assumptions for consumption and savings against the facility's total or, if available, sub-meter billing data.

With this method, all values, however determined, are stipulated. Thus, meaningful results require good estimates of unit water consumption and frequency of use. Modern water conservation devices usually have manufacturer-supplied consumption ratings. However, devices are subject to many variables. Thus, spot measurements will yield superior results.

Spot measurements are useful not only to quantify water consumption but also to make sure specific devices are assigned to appropriate device groups, and to verify that all devices assigned to the group have similar performance characteristics. Spot measurements are not called for with this M&V method because the water consumption characteristics of new plumbing devices are assumed to be known before they are approved for installation.

Water consumption savings are based on the following:

- Stipulated baseline consumption for each type of device
- Stipulated post-installation consumption for each type of device
- Number of devices, both baseline and post-installation, of each type
- Stipulated cycles or hours per year for each operating scenario, both baseline and post-installation.

27.3 Calculation of Savings in Water Consumption and Demand

27.3.1 Baseline Water Consumption

The baseline conditions identified in the pre-installation equipment survey will be defined either by the federal agency or the ESCO. If the baseline is defined by the federal agency, the ESCO will have an opportunity to verify the baseline. If the baseline is defined by the ESCO, the Federal agency will verify the baseline.

Steps involved in establishing the baseline water consumption are these:

- Conduct pre-installation facility survey.
- Determine flow rates of representative existing devices.

In the pre-installation survey, all devices to be changed are inventoried. Device locations and corresponding facility drawings should be included with the survey submittal. The surveys will include, in a set format, the type of device, the number of devices in each type, locations, units of measure for each device group, periods of service, and water consumption per unit of measure.

27.3.2 Adjustments to Baseline Water Consumption

After WCM installation, adjustments to baseline water consumption may be required because of factors such as remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

27.3.3 Post-Installation Water Consumption

The new equipment will be defined and surveyed by the ESCO and verified by the federal agency.

After new devices are installed, documentation must be done using the same procedures used for the baseline devices, with results entered in a standard survey form. See part 27.3.1. If no water consumption values are available yet for the new plumbing devices, or any doubt is raised about the water consumption figures supplied by the manufacturer, then another M&V method should be used. In either case, installation of the new devices and their proper operation should be field-verified.

27.3.4 Operating Hours/Cycles

Information about the usage of the device must be captured during the pre-installation facility survey. Usage factors must be consistent with the units of measurement applied to each device type, so that the product of the flow rate or cycle flow times the usage factor will determine the total consumption for the time period. For example:

1. A shower has a flow rate expressed in gpm; determine how many minutes the shower is used each year (or how many minutes per day and the number of active days each year).
2. A tank type toilet discharges a certain number of gallons per flush; determine how many times it is flushed each year (or how many times each day and the number of active days each year).

Once defined, the operating hours will be stipulated—i.e., agreed to by the federal agency and the ESCO. Sources of stipulated hours can be any of the following:

- Research reports or documents provided by vendors or third-parties
- Results from other projects in similar facilities

- Operator logs or documented schedules from building management systems (infrequent).

Operating periods or cycles can be estimated for each individual device or for groups of devices with similar applications and schedules. Each group type should have similar use patterns and comparable average operating hours. Examples of such groupings are the following:

- Shower usage in a 40-person barracks
- All sprinklers for an area covered by a single timer.

Note that baseline and post-installation total operating hours may differ.

See Appendix D for information on sampling.

27.4 Calculating Water Consumption Savings

The following is an example of a water savings calculation using method WCM-A-01.

Example: Calculating water savings using WCM-A-01

A tank-type toilet, rated by the manufacturer at 3 gallons per flush, is used an average of 20 times a day (per studies from similar facilities) throughout the year; the annual water consumption is:

$$3 \times 20 \times 365 = 21{,}900 \text{ gallons per year}$$

If the toilet is replaced with one that is rated by the manufacturer at 1.6 gallons per flush, and the usage is unchanged, the post-installation annual water consumption is:

$$1.6 \times 20 \times 365 = 11{,}680 \text{ gallons per year}$$

And the estimated savings in water consumption is:

$$21{,}900 - 11{,}680 = 10{,}220 \text{ gallons per year}$$

Table 27.1 is a summary of sample baseline and post-installation water consumption measurements and savings calculations.

27.5 Method-Specific Issues for M&V Plan

Specific M&V issues that may need to be addressed in the site-specific M&V plan and that are related to this water M&V method include these:

- Definition of operating scenarios for the devices affected by the WCM.
- Source and documentation of consumption and operating- cycle assumptions for each scenario, for baseline and post-installation cases.

Table 27.1 Example Reporting Format—Water Conservation Savings

Device/type	Device quantity	Unit of measure	Baseline rate	Periods/ year	Baseline consumption (gal/yr)	Post-installation rate	Post-installation consumption (gal/yr)	Savings (gal/yr)
Lavatory	6	gpm	3.0	100min/d 240 d/yr	432,000	1.5	213,000	216,000
Lavatory faucet	6	gpm	3.0	100min/d 240 d/y	432,000	0.5	72,000	360,000
Lavatory	2	gpm	3.0	90 min/d 365 d/yr	197,100	2.0	131,400	65,700
Shower	5	gpm	4.0	30 min/d 240 d/yr	144,000	1.5	54,000	90,000
Clothes washer	1	gal/wash	55	20 washes/ wk 52 wks/yr	57,200	35	36,400	20,800
Totals					1,262,300		509,800	752,500

28

Metered Flows and Stipulated or Metered Durations for Plumbing Devices

28.1 WCM Definition

Many water conservation projects focus simply on replacing existing plumbing devices (the baseline) with new devices. The new devices are designed to deliver water at low flow rates or low consumption per cycle during consistent operating schedules. Designs limit the flow and/or cycle consumption to fixed maximum values, usually stated in the product specifications. Other projects simply involve the changing of water consumption schedules.

For these projects, the operating schedules are known and consistent. Typical applications include water closet, urinal, irrigation head and shower head conversions, and irrigation schedule changes.

This M&V method is appropriate only for water conservation projects in which, for baseline and post-installation conditions, the following apply:

- Device flow rates and/or water consumption per cycle can be measured for each applicable water-consuming device (or group of devices).
- Device usage can be determined from short-term monitoring or from other surveys or research on typical units, because usage patterns are known or can be estimated with reasonable accuracy and operating schedules are consistent from one time period to the next.

28.2 Overview of Verification Method

Method WCM-A-02 assumes that the federal agency and the ESCO are confident that unit water consumption can be defined, measured, and stipulated for each device type, and that operating cycles (flushes, hours of use, or another parameter) can be quantified and stipulated.

Surveys are required to document existing (baseline) and new (post-installation) devices (sprinklers, toilets, etc.) and characteristics. The surveys should include the following information in a set format, preferably in a matrix that allows each device type to be listed by location:

- Generic type of device
- Location
- Number of devices (of the same type and flow) counted in each location
- Unit of measure for each device group (gpm flow, gallons per flush, etc.)
- Period of service in consistent units (hours per day, flushes per day, etc.)
- Water consumption per unit of measure, existing devices (base case)
- Water consumption per unit of measure, new devices.

Even though this method, in comparison to method WCM-A-01, requires measurement or metering of water flow for each type of water-consuming device, it is a good idea to conduct a “reality check” of the assumptions for consumption and savings against the facility's total, or, if available, sub-meter; billing data.

Existing devices are subject to many variables and usually will not display a flow rating; thus, this method can provide reliable data if metering is done correctly. Modern water conservation devices are usually rated by the manufacturers; however, published data should generally not be used for the documentation of a new installation. Comparison with measurements of existing conditions is required.

Flow measurements can be made either with flow meters or by volumetric means. Suitable flow meters are selected for appropriate accuracy, and they have flow ratings that conform to field conditions. Flow rates can also be determined by measuring how much water (i.e., its volume) is used or discharged during a measured time interval. For example, water discharged from a faucet is collected for a timed period of 2 minutes, and when measured is found to be exactly 5 gallons; the flow rate is 5 gallons divided by 2 minutes, or 2.5 gpm). Volumetric measurements are usually used to determine how much water is discharged during a set cycle, such as one flush of a water closet. Dishwashers and clothes washers also have set cycles, although care must be taken to recognize possible variations, such as water-saver cycles or extra rinse cycles.

Spot measurements are useful not only to quantify water consumption but also to make sure specific devices are assigned to appropriate device groups, and to verify that all devices assigned to the group have similar performance characteristics.

Savings estimates also require good estimates of how frequently each type of device is used or for how long it operates per day, week, or year. Frequency information may need to be determined by measuring how often each type of device is used, most likely by sample counts. Any surveys of this type must account for variables in user practices, such as shower duration, double-flushing of water closets, and the amount of rinsing that occurs during food preparation. Given these variables, it is often preferable to use results from published surveys that are representative of the actual field conditions, or use short-term metering to determine patterns during representative time periods.

Water consumption savings are based on the following:

- Measured baseline consumption for each type of device
- Measured post-installation consumption for each type of device (including possibly using manufacturers' flow measurements that are stipulated for use, assuming approval by the agency and ESCO)
- Number of devices, both baseline and post-installation, of each type
- Measured or stipulated cycles or hours per year for each operating scenario, both baseline and post-installation.

28.3 Calculation of Savings in Water Consumption and Demand

28.3.1 Baseline Water Consumption

The baseline conditions identified in the pre-installation equipment survey will be defined either by the federal agency or the ESCO. If the baseline is defined by the federal agency, the ESCO will have an opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline.

Steps involved in establishing the baseline water consumption are as follows:

- Conduct a pre-installation facility survey
- Determine flow rates of representative existing devices.

In the pre-installation survey, all devices to be changed are inventoried. Device locations and corresponding facility drawings should be included with the survey submittal. The surveys will include, in a set format, device types, number of devices of each type, locations, units of measure for each device group, periods of service, and water consumption per unit of measure.

28.3.2 Adjustments to Baseline Water Consumption

After WCM installation, adjustments to baseline water consumption may be required because of factors such as remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

28.3.3 Post-Installation Water Consumption

The new equipment will be defined and surveyed by the ESCO and verified by the federal agency.

After new devices are installed, spot metering may again be necessary, using the procedures that were used for the baseline devices, and entering results in a standard survey form. See part 28.3.1. In some instances, the manufacturer's water consumption values for the new devices can be used; however, if there is any doubt about the water consumption figures supplied by the manufacturer, metering should be used. In either case, installation of the new devices should be field verified.

28.3.4 Operating Hours/Cycles

Information about device usage must be captured during the pre-installation facility survey. Usage factors must be consistent with the units of measurement applied to each device type, so that the product of the flow rate or cycle flow times the usage factor will determine the total consumption for the time period. Examples:

1. A shower has a flow rate expressed in gpm; determine how many minutes the shower is used each year (or how many minutes per day and the number of active days each year).
2. A tank-type toilet discharges a certain number of gallons per flush; determine how many times it is flushed each year (or how many times each day and the number of active days each year).

Once defined, the operating hours will be stipulated—i.e., agreed to by the federal agency and the ESCO. Sources of stipulated hours can be any of the following:

- Pre-metering of representative devices by the ESCO or federal agency
- Research reports or documents provided by vendors or third parties
- Results from other projects in similar facilities
- Operator logs or documented schedules from building management systems (infrequent).

Operating periods or cycles can be estimated for each individual device or for groups of devices with similar applications and schedules. Each group type should have similar use patterns and comparable average operating hours. These are examples of such groupings:

- Kitchen sink usage in all two-bedroom apartments within a residential complex
- All top-load clothes washers (of the same rated load capacity) within a laundromat.

Note that baseline and post-installation total operating hours may differ.

See Appendix D for information on sampling.

28.4 Calculating Water Consumption Savings

The following is an example of water savings calculation using method WCM-A-02.

Example: Calculating water savings using WCM-A-02
.A tank-type toilet is measured to consume 3 gpf and is used on average 20 times a day (based on a facility survey) throughout the year; the annual water consumption is: 3 x 20 x 365 = 21,900 gallons per year If the toilet is replaced with one that is measured to consume 1.6 gpf, and the usage is unchanged, the post-installation annual water consumption is 1.6 x 20 x 365 = 11,680 gallons per year And the savings in water consumption is 21,900 - 11,680 = 10,220 gallons per year

Table 28.1 is a summary of sample baseline and post-installation water consumption measurements and savings calculations using the above equations.

28.5 Method Specific Issues for the M&V Plan

Specific M&V issues that may need to be addressed in the site-specific M&V plans and that are related to this M&V method include the following:

- Defining operating scenarios for the devices affected by the WCM.
- Providing a source and documentation for any consumption and operating cycle assumptions for each scenario, for baseline and post-installation case.
- Stipulating a meter specification and spot metering methodology, including calibration methods.
- Providing a source of any consumption and operating-cycle assumptions used in developing baseline and post-installation assumptions.

Table 28.1: Example Reporting Format—Water Conservation Savings

Device/type	Device quantity	Unit of measure	Baseline rate	Periods/year	Baseline consumption (gals/yr)	Post-installation rate	Post-installation consumption (gal/yr)	Savings (gal/yr)
Lavatory	6	gpm	3.0	100 min/d 240 d/yr	432,000	1.5	216,000	216,000
Lavatory Faucet	6	gpm	3.0	100 min/d 240 d/yr	432,000	0.5	72,000	360,000
Lavatory	2	gpm	3.0	90 min/d 365 d/yr	197,100	2.0	131,400	65,700
Shower	5	gpm	4.0	30 min/d 240 d/yr	144,000	1.5	54,000	90,000
Clothes Washer	1	gal/wash	55	20 washes/wk 52 wks/yr	27,200	35	36,400	20,800
Totals					1,262,300		509,800	752,500

29

All Water Uses Compatible with Sub-Metering or Monitoring

29.1 WCM Definition

Some water conservation projects can easily be sub-metered, and others are complex or large enough that the added cost of sub-metering is justified. Sub-metering is indicated when the water-consuming devices do not have constant flows, water usage patterns are expected to change or vary unpredictably, operating schedules are erratic (and can be known only through monitoring), and/or metering costs are small in comparison to other project costs. Sub-metering, if done properly, often provides very useful information and the most accurate savings estimates.

Typical applications include retrofits that are done only in a portion of a very large building, multibuilding developments, irrigation projects, and certain HVAC systems, especially those with evaporative cooling.

This M&V method is appropriate only for water conservation projects in which, for the baseline and post-installation conditions, the following apply:

- Water flowing to most of the water conservation project, or all of it, can be, or is, measured by sub-metering at one or more points.
- Periods of measurement, for the baseline and post-installation, can be defined for comparable seasons and/or regular usage patterns.

29.2 Overview of Verification Method

Method WCM-B-01 assumes that the federal agency and the ESCO agree to use measured flows of supply water as the basis for evaluating the savings from a water conservation project, including impacts of any leaks, occupancy changes, or other effects that may be reflected in the measured values.

Water flowing to or through for any group of devices is likely to change over a period of time. Periodic or continuous monitoring of the project with sub-metering will help identify sudden changes—e.g., the onset of leaks or the lax irrigation practices of gardeners. Ongoing metering improves the chances of maintaining full savings from the project, and perhaps increasing savings beyond expectations by using information feedback.

Surveys are required to document existing (baseline) and new (post-installation) devices (sprinkler heads, toilets, etc.). Surveys should include the following information in a set format, preferably in a matrix that allows each device type to be listed by location:

- Generic type of water delivery device
- Location
- Number of devices (of the same type and flow) in each location
- Unit of measure for each device group (gpm flow, gpf, etc.)
- Period of service in consistent units (hours per day, flushes per day, etc.)
- Water consumption per unit of measure, existing devices (base case)
- Predicted water consumption per unit of measure, new devices.

The number of devices will normally be determined by device counts during field observations. In instances in which construction modules have been repeated and construction drawings or other documents show the complete installation, device counts may be extrapolated from counts in representative modules.

Water consumption savings are based on the following:

- Measured baseline consumption for the project
- Measured post-installation consumption for the project
- Metering and/or analysis of independent variables that affect baseline and post-installation water-use.

Although this method requires metering water flow from individual devices or groups of devices, "reality checking" results against utility bills is still recommended.

29.3 Calculating Savings in Water Consumption and Demand

29.3.1 Baseline Water Consumption

The baseline conditions identified in the pre-installation equipment survey will be defined by either the federal agency or the ESCO. If the baseline is defined by the federal agency, the ESCO will have an opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline.

Steps involved in establishing the baseline water consumption are as follows:

- Conduct a pre-installation facility survey
- Determine flow rates by sub-metering
- Document the independent variables that affect baseline water-use (e.g., weather or occupancy).

Pre-Installation Facility Survey

In the pre-installation survey, all devices to be changed are inventoried. Device locations and corresponding facility drawings should be included with the survey submittal. The surveys will include, in a set format, device types, and number of devices of each type, locations, units of measure for each device group, periods of service, and estimated water consumption per unit of measure.

Flow Determination By Sub-metering

Sub-metered data must be collected and recorded for the water conservation project. If meter readings are taken at more than one independent location, water consumption for the same periods should be added together. Results may need to be interpolated or extrapolated if meter locations do not coincide exactly with water flows within the project boundaries. Readings must encompass a period long enough to average normal fluctuations in water-use (e.g., daily and weekly patterns of use).

In some facilities, water-use may change seasonally (e.g., rainy and dry seasons), so separate data will be needed for each season.

29.3.2 Adjustments to Baseline Water Consumption

After WCM installation, adjustments to baseline water consumption may be required because of factors such as remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

29.3.3 Post-Installation Water Consumption

The new equipment will be defined and surveyed by the ESCO and verified by the federal agency.

After new devices are installed, installation and proper operation of the new devices should be field-verified. Sub-metered water consumption measurements should be repeated at the same metering points and for periods of measurement that are either (a) continuous or (b) for each year of the agreement, comparable to those used in the pre-installation measurements.

29.3.4 Operating Hours/Cycles

Information about water consumption patterns must be captured during the pre-installation facility survey. At a minimum, the record should define the types of water consumption devices and how many units of each type are in active use. Additional data collection is encouraged for how intensively the equipment is used and hours of service. This information provides the means to confirm that metered data are meeting expectations. It also provides a comparative record, should consumption patterns change. An adjustment will be needed if baseline and post-installation operating conditions differ.

29.4 Calculating Water Consumption Savings

The following is an example of a water savings calculation using method WCM-B-01.

Example: Calculating water savings using WCM-B-01

A 540-unit military complex is surveyed, and appropriate baseline information is recorded about existing conditions, including occupancy. The project excludes irrigation and other common uses. Sub-metering instruments are installed within a representative sample of housing units and measurements are recorded for one month. Usage patterns are found to be stable during the month and consistent with the survey data. After installation of the WCMs, measurements were repeated for another month, with no change in occupancy. Monthly water consumption was measured as follows:

	Pre-installation	**Post-installation**
Sub-meter 1	2,440,000 gallons	1,890,000 gallons
Sub-meter 2	1,966,000 gallons	1,585,000 gallons
Etc.		
Total Consumption	4,406,000 gallons	3,475,000 gallons

The savings in monthly water consumption is:

$$4{,}406{,}000 - 3{,}475{,}000 = 931{,}000 \text{ gallons}$$

Should a change in occupancy have occurred a method would be needed to adjust the baseline.

29.5 Method-Specific Issues for the M&V Plan

Specific M&V issues that may need to be addressed in the site-specific M&V plan and that are related to this water M&V method include the following:

- Definitions of project scope and sub-metering locations
- Assessment of active and nonoperating segments of the project
- Validation of sub-metered data with inventory data
- Meter specifications and metering methodology
- Independent variables documentation and/or monitoring methodology and methods for adjusting baselines (if and when necessary)
- Sources and documentation of any assumptions.

30

All Water Uses Compatible with Whole-Facility Metering

30.1 WCM Definition

Measurement and verification for some water conservation projects can best be achieved with whole-facility metering, usually with the servicing utility's own water supply meter. All end-use technologies can be verified with Option C, provided that the reduction in consumption is larger than the associated modeling error—i.e., the savings are not “lost in the noise.” This option may be used in cases where there is a high degree of interaction between different water conservation measures, and/or it is difficult to measure individual component savings. Accounting for changes is the major challenge associated with Option C, particularly for long-term contracts.

“Whole-building” metering may include several buildings or an entire complex. Whole-building metering is appropriate when (a) water-consuming devices do not have constant flows, and (b) the use of splintering is not practical or is prohibitively expensive. Compared with methods relying on stipulated values or spot measurements, whole-building metering may provide superior information and improve the accuracy of the savings estimates. Typical applications include large scale plumbing fixture retrofits and irrigation projects.

This M&V method is appropriate when the following apply:

- The utility meter (or other whole-building meter) can measure water flowing to most or all of the water conservation project.
- Periods of measurement, for the baseline and post-installation, can be defined for comparable seasons and/or other usage patterns.
- Project water savings are at least 20% of the water consumption recorded by the whole-facility meter.

30.2 Overview of Verification Method

Method WCM-C-01 assumes that the federal agency and the ESCO agree to use whole-facility measured-supply water flows as the basis for evaluating savings from a water conservation project, including impacts of any leaks, occupancy changes, or other effects which may be reflected in the measured values.

Water demand in any project is likely to change over time. Periodic or continuous monitoring of the project with whole-building metering will help identify changes, such as the onset of leaks or lax irrigation practices of gardeners. Ongoing metering improves the opportunity for maintaining full savings from the project, and perhaps increasing the savings beyond expectations using information feedback. However, whole-facility metering does not help pinpoint changes as well as sub-metering does.

Surveys are required to document existing (baseline) and new (post-installation) devices. Surveys should include the following information in a set format, preferably in a matrix that allows each device type to be listed by location:

- Generic type of water delivery device
- Location
- Number of devices (of the same type and flow) in each location
- Unit of measure for each device group (gpm flow, gpf, etc.)
- Period of service in consistent units (hours per day, flushes per day, etc.)
- Water consumption per unit of measure, existing devices (base case)
- Predicted water consumption per unit of measure, new devices.

This method does not require measurements or metering of water flow from individual devices or other water-delivery devices; however, "reality checking" results requires reasonable estimates of unit water consumption, number of devices, and frequency of use. Flows recorded with metering should be consistent with these estimates, within appropriate allowances. The number of devices will normally be determined by device counts during field observations. In instances where construction modules have been repeated and construction drawings or other documents show the complete installation, device counts may be extrapolated from counts in representative modules.

Readings must be taken and recorded regularly, either monthly or at a more frequent interval. Recording meters that provide electronic data (with telemetry) may be very valuable tools.

Water consumption savings are based on the following:

- Measured baseline consumption for the project
- Measured post-installation consumption for the project
- Metering and/or analysis of independent variables that effect baseline and post-installation energy use.

30.3 Calculating Savings in Water Consumption and Demand

30.3.1 Baseline Water Consumption

The baseline conditions identified in the pre-installation equipment survey will be defined either by the federal agency or by the ESCO. If the baseline is defined by the federal agency, the ESCO will have an opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline.

Steps involved in establishing the baseline water consumption are as follows:

- Conduct a pre-installation facility survey
- Determine flow rates by whole-building metering
- Document the independent variables that affect baseline water-use (e.g., occupancy and weather).

Pre-Installation Facility Survey

In the pre-installation survey, an inventory is made of all plumbing devices and other water-consuming devices to be changed. Device locations and the corresponding facility drawing should be included with the survey submittal. The surveys will include, in a set format, device types and number of devices of each type, locations, units of measure for each device group, periods of service, and estimated water consumption per unit of measure. This information is required primarily in case any baseline adjustments are required during the term of the agreement.

Flow Determination by Whole-Building Metering

Metered data must be collected and recorded for the water conservation project. Results may need to be interpolated or extrapolated if meter locations do not coincide exactly with water flows within project boundaries. Readings must be taken for a period long enough to average out normal fluctuations in water use (e.g., daily and weekly patterns of use).

In some facilities, water use may change seasonally (e.g., rainy and dry seasons), so separate data will be needed for each season.

When readings are taken by the utility, they will often be for periods a little longer or shorter than one month; such readings should be adjusted in proportion to the number of days included in the reading interval, to reflect corrected values for exactly one month at a time.

Documentation of Independent Variables

A regression analysis is required to properly estimate savings using whole-facility analysis. To complete the analysis, data on independent variables that affect water use need to be collected throughout the term of the agreement and for the baseline. Whole-facility, or billing, analysis is discussed in Chapter 21.

30.3.2 Adjustments to Baseline Water Consumption

After WCM installation, adjustments to baseline water consumption may be required because of factors such as remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

30.3.3 Post-Installation Water Consumption

The new equipment will be defined and surveyed by the ESCO and verified by the federal agency.

After new devices are installed, installation and proper operation of the new devices should be field-verified. Whole-building metered water consumption measurements should be repeated at the same metering location and for periods of measurement that are either (a) continuous or (b) for each year of the agreement, comparable to those used in the baseline measurements.

30.4 Calculating Water Consumption Savings

The following is an example of a water savings calculation using method WCM-C-01.

Example: Calculating water savings using WCM-C-01

A facility receives water from its utility through two existing meters. One meter is dedicated to a central chilled water plant, where most of the water is used to reject heat in a once-through process. The plant facilities are surveyed, and appropriate baseline information is recorded about existing conditions, including miscellaneous water uses. Utility billing records and weather data are used to define a statistically valid relationship (an equation) between cooling degree-days and water flow. A WCM is installed in the form of a cooling tower that provides the same cooling capacity. After installation, water consumption data are again obtained from the utility. Using the collected, post-installation weather data, adjustments in the baseline consumption data are made to establish an adjusted annual baseline for the once-through cooling process for comparison with post-installation consumption. Annual water consumption and savings were determined to be:

	Baseline	**Post-Installation**
Metered consumption	5,316,000 gallons	250,000 gallons
Consumption adjusted to annual value using typical weather data	5,056,000 gallons	250,000 gallons

The savings in annual water consumption is:

5,056,000 - 250,000 = 4,806,000 gallons per year.

30.5 Method-Specific Issues for the M&V Plan

M&V issues that need to be addressed in a site-specific M&V plan and that are related to this M&V method include the following:

- Definitions of project scope and sub-metering locations
- Validation (reality check) of meter water consumption data with inventory data
- Meter specifications and metering methodology
- Documentation and/or monitoring methodology for independent variables and methods for adjusting baselines (if and when necessary)
- Criteria for determining acceptable accuracy in analysis equations, e.g, minimum R2 values for regression models
- Sources and documentation of any assumptions concerning variables used in analysis equations.

31

Calibrated Simulation Analysis of Water-Consuming Systems

31.1 WCM Definition

Modeling, or computerized simulation, techniques are used for measurement and verification when impacts of WCMs are too complex to analyze cost-effectively with Option B, when the savings are too small to show up in whole-facility meter analysis (Option C), or when Option A methods cannot provide the level of detail or accuracy required.

Few computer-based modeling tools have been developed to analyze water conservation measures. Those that are available are not as sophisticated or widely validated as their building-energy-simulation counterparts. More sophisticated engineering simulation tools have been developed for complex water problems such as network flow, but they are generally not suitable for analyzing water conservation measures. The relative lack of water conservation modeling tools may be attributed partly to a slower start for efforts in the water conservation field; but the primary consideration is that most water conservation projects are generally not complex, and formal computational tools generally are not needed. Thus, most projects should take advantage of Option A, B, or C.

Option D may be appropriate when the water project is unusually complex, when existing metering is not congruent with the project, and/or when long-term sub-metering would be too difficult or costly to implement. Applications might include WCMs involving evaporative cooling systems or irrigation projects using moisture sensors.

31.2 Overview of Verification Method

Computer simulations and other modeling techniques that are used to predict water consumption and demand are generally recognized as being more of an art form than an exact science. The reason for this view is that water-use in a building or other development can depend on a large number of factors, many of which are difficult to predict or are beyond the control of project managers, and are thus hard to "program" into a model. Factors include the unique behaviors of individuals who use the facilities.

A key element of this method is calibrating the model with (a) utility metering data and/or (b) short-term or spot metering of individual devices or systems. In some facilities, the utilization factor may change seasonally (e.g., dry versus rainy season), and appropriate data will be needed for each season. If the simulation results do not agree with measured data, often only trained and experience personnel are able to determine the cause of the discrepancy and correct the model.

Comparative data are required to document existing (baseline) and new (post-installation) characteristics. Data may be available in the form of inventories and engineering documents (drawings, specifications). These data should be reflected in the model's input parameters; however, it is not sufficient that there is a change in simulated water flow or consumption. Even if there is agreement that additional documentation is not needed for the project as a whole, a suitable sampling plan is still required in which first-hand observations are made both before and after the WCM, to confirm that the physical changes have in fact been made.

It is usually helpful to summarize the following information and present it in a set format, preferably in a matrix that allows each device type to be listed by location:

- Generic type of device or other water delivery device
- Location
- Number of devices (of the same type and flow) in each location
- Unit of measure for each device group (gpm flow, gpf, etc.)
- Period of service in consistent units (hours per day, flushes per day, etc.)
- Water consumption per unit of measure, existing devices (base case)
- Water consumption per unit of measure, new devices.

Water consumption savings are based on the following:

- Simulated baseline consumption for the project
- Simulated post-installation consumption for the project
- Analysis of the effects of independent variables in order to determine any necessary baseline adjustments.

31.3 Calculating Savings in Water Consumption and Demand

31.3.1 Baseline Water Consumption

The baseline conditions identified in the pre-installation equipment survey will be defined either by the federal agency or by the ESCO. If the baseline is defined by the federal agency, the ESCO will have the opportunity to verify the baseline. If the baseline is defined by the ESCO, the federal agency will verify the baseline. Steps involved in determining the baseline water consumption are as follows:

- Conduct a pre-installation facility survey or sampling
- Perform modeling to compute the consumption
- Collect metering data to calibrate the model
- Document the independent variables that affect baseline water-use.

Pre-Installation Facility Survey

In the pre-installation survey, an inventory is made of all plumbing devices and other water-consuming devices to be changed. Device locations and corresponding facility drawings should be included with the survey submittal. The surveys will include, in a set format, device types and the number of devices of each type, locations, units of measure for each device group, periods of service, and estimated water consumption per unit of measure.

Modeling and Calibration

Measurement and verification of WCMs using computer simulation or other modeling approaches involves the following steps:

- Select appropriate simulation software or other computational basis.
- Conduct detailed site surveys, collecting water-related building and equipment data.
- Select appropriate program inputs such as weather, occupancy schedules, and irrigation schedules.
- Select appropriate calibration data, usually from utility billings or sub-metering.
- Input baseline data into the model; simulate the baseline conditions.
- Calibrate the baseline model.
- Input WCM specifications and simulate the post-installation conditions.
- Estimate energy-savings by comparing the water consumption predicted by the baseline and post-installation models.

More information on calibrated simulation can be found in Chapter 24.

31.3.2 Adjustments to Baseline Water Consumption

After WCM installation, adjustments to baseline water consumption may be required because of factors such as remodeling or changes in occupancy. Methods for making adjustments should be specified in the site-specific M&V plan.

31.3.3 Post-Installation Water Consumption

The new equipment will be defined and surveyed by the ESCO and verified by the federal agency. Installation of the new devices and proper operation should be field-verified. Unless field changes are observed, the previously modeled post-installation consumption figures may be accepted without change.

31.3.4 Operating Hours/Cycles

Information about water consumption patterns must be captured during the pre-installation facility survey. At a minimum, the record should define the types of water consumption devices and how many units of each type are in active use. Additional data collection is encouraged for how intensively the equipment is used and hours of service. This information and the utility billing data provide a means for cross-checking that the modeled results are meeting expectations. It also provides a comparative record, in case later consumption patterns change.

An adjustment will be needed if baseline and post-installation total operating conditions differ.

31.4 Calculating Water Consumption Savings

The following is an example of a water savings calculation using method WCM-D-01.

Example: Calculating water savings using method WCM-C-01

A patient wing of a hospital is to undergo extensive remodeling in part to install water-economizer plumbing fixtures. Utility metering is not applicable and sub-metering is not feasible, because the project has a relatively low economic value. The facilities are surveyed, appropriate baseline information is recorded, and a baseline model is constructed. Simulated results are also obtained from the model for input data representative of the changes being made. Both baseline and retrofit fixtures are metered to validate flow assumptions in the baseline and post-installation models. After installation of the WCMs, field observations confirm that the physical changes were made as planned. Annual water consumption and savings are simulated to be:

Simulated baseline consumption: 1,250,000 gallons

Simulated post-installation consumption: 660,000 gallons

The water saved each year is:

1,250,000 - 660,000 = 590,000 gallons

31.5 Method-Specific Issues for the M&V Plan

M&V issues that need to be addressed in the site-specific M&V plan and that are related to this water M&V method include the following:

- Definitions of project scope and submetering locations
- Definition of models to be used, who will conduct the modeling, how the models will be calibrated, what the criteria will be for establishing calibration, and the documentation of the models that will be provided
- Documentation and/or monitoring methodology for independent variables and methods for adjusting baselines (if and when necessary)
- Sources and documentation of any assumptions to be used in models.